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ENERGY CALIBRATION OF THE "ORION" SPECTROGRAPH

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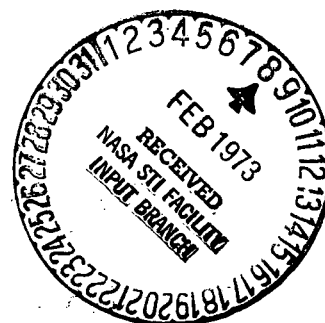
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ENERGY CALIBRATION OF THE "ORION" SPECTROGRAPH

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ABSTRACT. The "Orion" telescope with a spectrograph designed to obtain shortwave spectrograms of the stars, was energy-calibrated in the range of 2000-3800 Å before its installation in the "Salyut" orbital station. Synchrotron radiation has been used from the electronic circular accelerator, with maximum energy of electrons 6 GeV. The calibration resulted in the curve of relative sensitivity of the entire "Orion" optical system and the photoemulsion applied. This curve can now be used to determine the law of the actual distribution of energy in the continuous spectrum of stars.

The "Orion" telescope with a spectrograph designed for obtaining shortwave ^{/36*} spectrograms of stars, prior to installation aboard the "Salyut" orbital station [1, 2] underwent energy calibration in its working range from 2000 to 3800 Å. The objective of the calibration was to find the curve of relative spectral sensitivity of the entire optical system with a radiation detector in the indicated wavelength range.

The "Orion" optical system consists of the following elements [1]:

a large mirror, coated with aluminum;

a small mirror, (Mersenne system), coated with aluminum.

The relative aperture of the Mersenne telescope was 1:5;

a concave diffraction grating (relative aperture 1:5), number of rulings 1,200 per 1 mm, plotted on an aluminum layer. The grating gives a concentration at 2600 Å. The optical system of this spectrograph is of the Wadsworth type. The angle of incidence of the light beam on the grating is 18.5°;

a plane-parallel quartz plate with a thickness of 2 mm, serving as a light filter for eliminating the second order of the spectrum (region shorter than 1900 Å);

a photoemulsion of the UFSh-4 type as the radiation detector [3].

* Numbers in the margin indicate pagination in the foreign text.

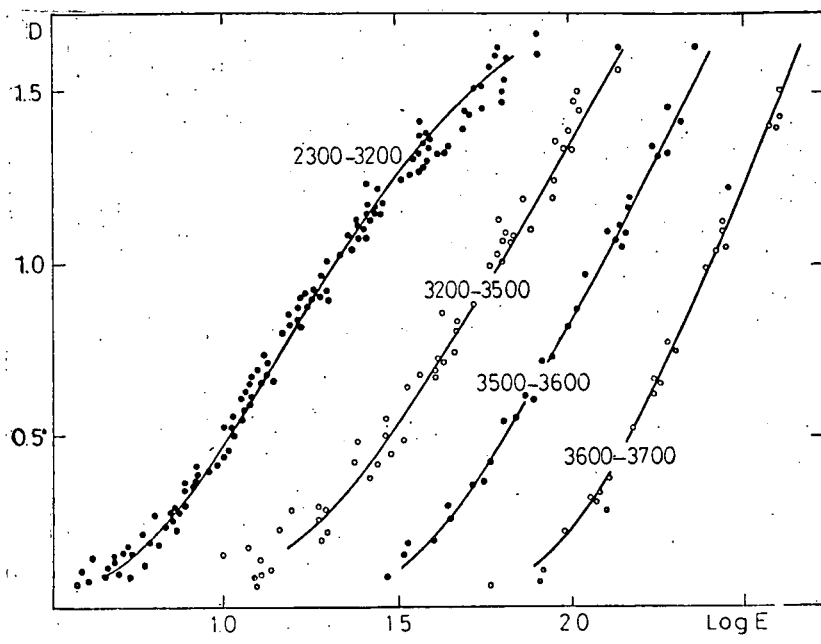


Figure 1. Characteristic curves of UFSH-4 film in different wavelength ranges.

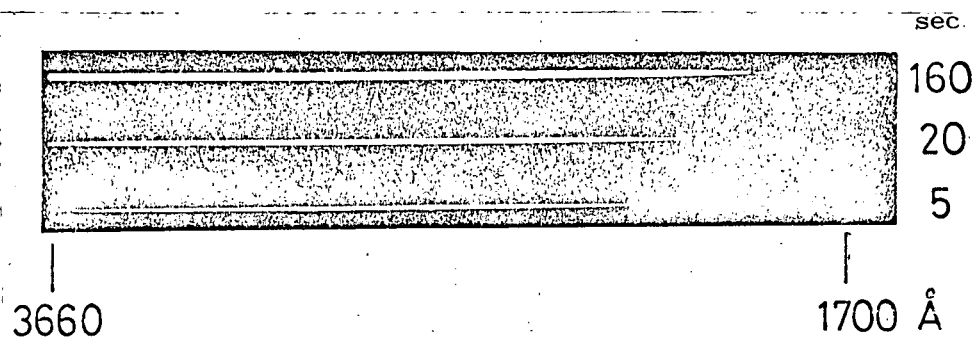


Figure 2. Samples of spectrograms of synchrotron radiation obtained using a telescope with the "Orion" spectrograph.

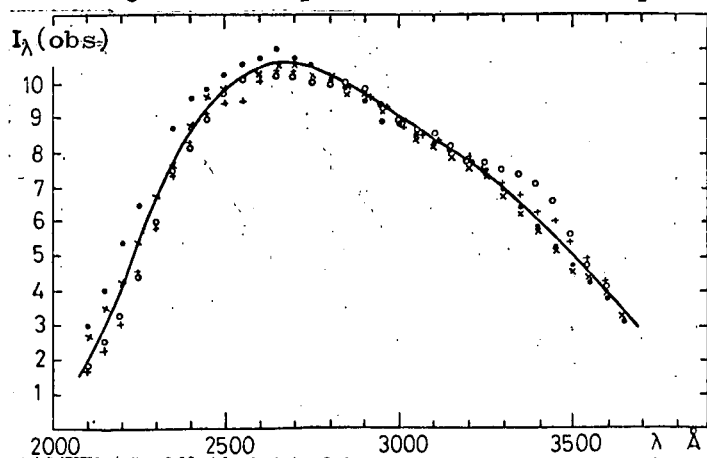


Figure 3. "Observed" energy distribution in the spectrum of synchrotron radiation obtained using the "Orion."

Energy calibration was accomplished using the synchrotron radiation from the annular electron accelerator at the Yerevan Physics Institute. A description of the synchrotron apparatus created specially for the purposes of energy calibration of the astronomical apparatus, principal characteristics of the synchrotron beam, calibration method, etc., are given in [4].

The calibration itself was done in the following way. The "Orion" apparatus, that is, the telescope and spectrograph, was completely enclosed in a vacuum chamber situated at the end of the synchrotron apparatus. The spectrograph magazine had been loaded ahead of time with working photographic film. After reaching the necessary vacuum level in the chamber ($\sim 10^{-3}$ mm) a series of synchrotron radiation spectrograms was obtained with different exposures through an entrance diaphragm of a stipulated size mounted in front of the "Orion" main mirror. A characteristic curve was constructed using the spectrograms obtained on this same film (UFSH-4), but using a laboratory quartz spectrograph. /37

Four such curves corresponding to different wavelength ranges (Figure 1) were constructed. It should be noted that the slopes of these curves, constructed for fresh UFSH-4 film, differ appreciably from the slopes of characteristic curves constructed for the same type of film but which had been a long time in space (see Figure 2 in [1]).

Since the radiation flux reaching the synchrotron apparatus vacuum chamber is rather great (see [4]), in order to obtain normal blackenings on the film it is necessary that the entrance aperture of the telescope be greatly diaphragmed to 2 x 2 mm even when working with exposures of a few seconds.

Figure 2 shows samples of synchrotron radiation spectrograms obtained using the "Orion."

The processing of four such spectrograms gave the curve of distribution of continuous energy in a spectrogram registered on photographic film after the synchrotron radiation had passed through all elements of the optical system, uncorrected for sensitivity change in the stipulated wavelength range. We will call this the "observed" curve (Figure 3). /38

The relative sensitivity of the optical system + emulsion combination at this wavelength is determined by the δ_λ parameter and is expressed in the following form

$$\delta_{\lambda} = \frac{I_{\lambda}(\text{synchr})}{I_{\lambda}(\text{obs})}, \quad (1) \quad \underline{/39}$$

where $I_{\lambda}(\text{obs})$ is the intensity (in relative units) of radiation in the observed spectrum and at the stipulated wavelength, and $I_{\lambda}(\text{synchr})$ is the intensity of radiation (also in relative units) in the source spectrum, in this case in the synchrotron radiation spectrum. The latter is rather well known (for details see [4]). It is interesting to note that the synchrotron radiation spectrum in the wavelength range with which we are concerned (2000-3800 Å) is virtually not dependent on the energy and flux of electrons and is constant in all accelerator operating regimes; this spectrum is represented graphically in Figure 4.

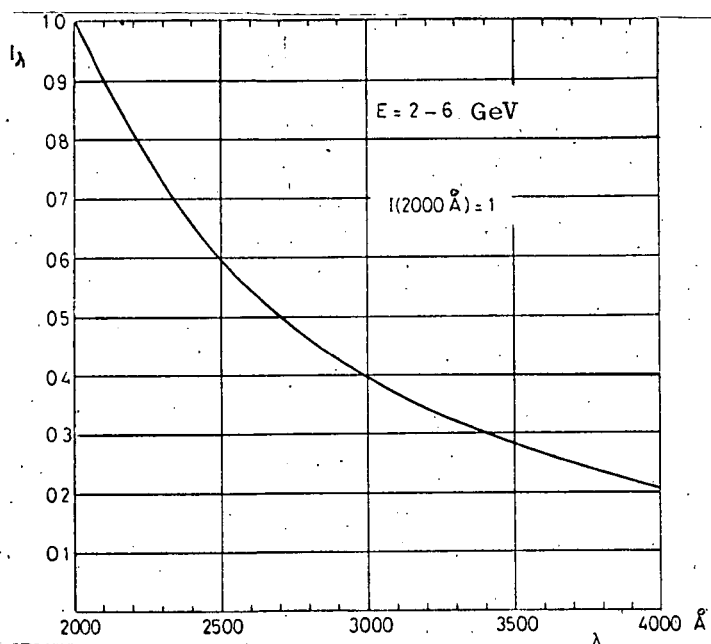


Figure 4. Energy distribution in spectrum of synchrotron radiation in electron energy interval 2-6 GeV (radiation intensity was assigned the value unity at $\lambda = 2000$ Å).

Thus, we know $I_{\lambda}(\text{obs})$ (Figure 3) and $I_{\lambda}(\text{synchr})$ (Figure 4). Using them we find from (1) the relative sensitivity of the "Orion," that is, the function δ_{λ} ; it is represented graphically in Figure 5 in arbitrary units. This curve is shown without corrections for optical system astigmatism and for broadening of the spectrogram.

Having the function δ_{λ} , it is easy to find the true (relative) energy distribution in the spectrum of any star whose spectrogram is obtained using the "Orion" under exoatmospheric conditions. For this purpose it is sufficient /40

to multiply the observed intensity I_λ on the spectrogram by the δ_λ value corresponding to the particular wavelength.

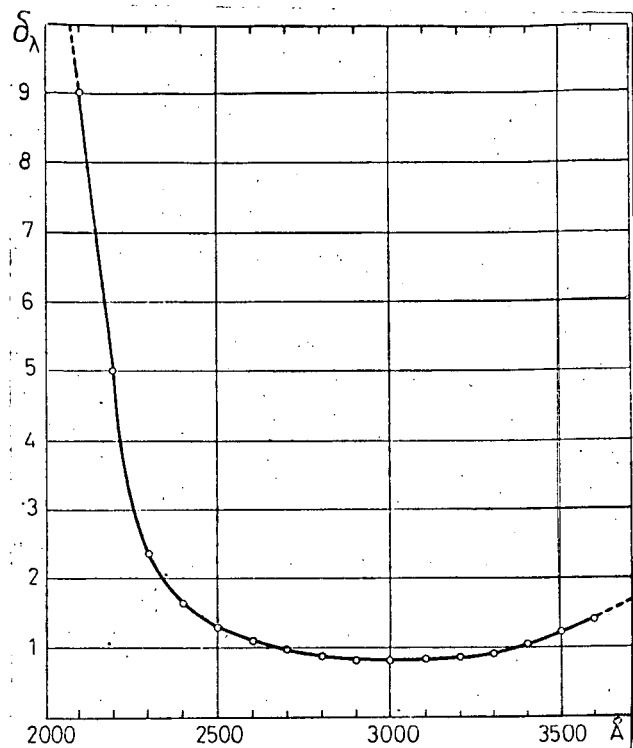


Figure 5. Curve of relative spectral sensitivity of the "Orion" system (reduction curve).

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